

### M.5.3.6 Ceramic Immobilization Alternative

Studies of evaluation basis accidents and beyond evaluation basis accidents have been performed for a ceramic immobilized facility in the *Fissile Material Disposition Program PEIS Data Call Input Report: Ceramic Immobilization Facility with Radionuclides*. The studies postulated a set of accidents scenarios that were representative of the risks and consequences for workers and the public that can be expected if the facility were constructed and operated. Although not all potential accidents were addressed, those that were postulated have consequences and risk that are expected to envelop the consequences and risks of an operating facility. In this manner, no other credible accidents with an expected frequency of occurrence larger than  $1.0 \times 10^{-7}$  per year are anticipated that will have consequences and risks larger than those described in this section. The potential for an aircraft crash has been considered and dismissed because the probability of a crash into a facility and causing sufficient damage to release Pu is much less than  $10^{-7}/\text{yr}$ .

#### M.5.3.6.1 Accident Scenarios and Source Terms

A wide range of hazardous conditions and potential accidents were identified as candidates to represent the risks to workers and the public of operating the facility. Through a screening process, nine evaluation basis accidents and four beyond evaluation basis accidents were selected for further definition and analysis. Descriptive information on these accidents is provided in Tables M.5.3.6.1-1 and M.5.3.6.1-2. Accident source term information is provided in Tables M.5.3.6.1-3 and M.5.3.6.1-4. Descriptions of accident scenarios are provided in Table M.5.3.6.1-5.

**Table M.5.3.6.1-1. Evaluation Basis Accident Scenarios for the Ceramic Immobilization Alternative**

Accident Scenario	Accident Frequency (per year)	Source Term at Risk	Source Term Released to Environment
Earthquake	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	7 kg Pu	$7.0 \times 10^{-6}$ g Pu
Tornado	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	No Release	No Release
Flood	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	No Release	No Release
Glovebox fire	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	7 kg Pu	$7.0 \times 10^{-6}$ g Pu
Glovebox nuclear criticality	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	$10^{18}$ fissions. Release fractions: 1.0 noble gases, 0.25 halogens.	a
Mixing tank nuclear criticality	$1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$	$1.0 \times 10^{19}$ fissions total. $1.0 \times 10^{18}$ fissions initial, 47 pulses of $1.0 \times 10^{17}$ fissions at 10 minute intervals. Release fractions: 1.0 noble gases, 0.25 halogens.	a
Bellows drop	$1.0 \times 10^{-4}$ to 0.01	4 kg Pu 4,330 Ci Cs	$4.0 \times 10^{-9}$ g Pu $4.3 \times 10^{-9}$ Ci Cs
Canister drop	$1.0 \times 10^{-4}$ to 0.01	No Release	No Release
Cs capsule drop	$1.0 \times 10^{-4}$ to 0.01	$4.0 \times 10^7$ Ci Cs	$4.0 \times 10^{-5}$ Ci Cs
Plutonyl nitrate dissolver spill	0.01 to 0.1	0.4 kg Pu	$2.4 \times 10^{-11}$ g Pu
Calciner feed spill	0.01 to 0.1	2.5 kg Pu 2,740 Ci Cs	$1.25 \times 10^{-10}$ g Pu $1.37 \times 10^{-10}$ Ci Cs
Calciner product spill	0.01 to 0.1	5 kg Pu 5,480 Ci Cs	$3.5 \times 10^{-8}$ g Pu $3.8 \times 10^{-8}$ Ci Cs
Loss of off-site power	0.01 to 0.1	No Release	No Release

<sup>a</sup> See Table M.5.3.6.1-3.

Source: LLNL 1996d; NRC 1979a.

**Table M.5.3.6.1-2. Beyond Evaluation Basis Accident Scenarios for the Ceramic Immobilization Alternative**

Accident Scenario	Accident Frequency (per year)	Source Term at Risk	Source Term Released to Environment
Cs fire	<1.0x10 <sup>-6</sup>	1.3x10 <sup>6</sup> Ci Cs	1.3x10 <sup>-5</sup> Ci Cs
Process cell fire	<1.0x10 <sup>-6</sup>	50 kg Pu	5.0x10 <sup>-7</sup> g Pu
Nuclear criticality	<1.0x10 <sup>-6</sup>	3.0x10 <sup>20</sup> fissions total. 5.0x10 <sup>19</sup> fissions initial, 47 pulses of 5.0x10 <sup>18</sup> fissions at 10 minute intervals. Release fractions: 1.0 noble gases, 0.25 halogens.	<sup>a</sup>
Uncontrolled chemical reaction	<1.0x10 <sup>-6</sup>	25 kg Pu 27,400 Ci Cs	2.5x10 <sup>-7</sup> g Pu 2.74x10 <sup>-7</sup> Ci Cs

<sup>a</sup> See Table M.5.3.6.1-4.

Source: LLNL 1996d; NRC 1979a.

Table M.5.3.6.1-3. Ceramic Immobilization Alternative Evaluation Basis Accident Source Terms

Accident Scenario										
Accident Parameter	Earthquake	Glovebox Fire	Glovebox Nuclear Criticality <sup>a</sup>	Mixing Tank Nuclear Criticality <sup>a</sup>	Bellows Drop	Cs Capsule Drop	Plutonyl Nitrate Dissolver Spill	Calciner Feed Spill	Calciner Product Spill	
Frequency of occurrence <sup>b</sup> (per year)	1.0x10 <sup>-5</sup>	1.0x10 <sup>-5</sup>	1.0x10 <sup>-5</sup>	1.0x10 <sup>-5</sup>	1.0x10 <sup>-3</sup>	1.0x10 <sup>-3</sup>	0.05	0.05	0.05	
Pu released to environment (g)	7.0x10 <sup>-6</sup>	7.0x10 <sup>-6</sup>	NA	NA	4.0x10 <sup>-9</sup>	NA	2.4x10 <sup>-11</sup>	1.25x10 <sup>-10</sup>	3.5x10 <sup>-8</sup>	
Cs released to environment (Ci)	NA	NA	NA	NA	4.3x10 <sup>-9</sup>	4.0x10 <sup>-5</sup>	NA	1.37x10 <sup>-10</sup>	3.8x10 <sup>-8</sup>	
Fissions	NA	NA	1.0x10 <sup>18</sup>	1.0x10 <sup>19</sup>	NA	NA	NA	NA	NA	
Isotope Released to Environment (Ci)										
Pu-238	1.11x10 <sup>-8</sup>	1.11x10 <sup>-8</sup>	0	0	6.32x10 <sup>-12</sup>	0	3.79x10 <sup>-14</sup>	1.98x10 <sup>-13</sup>	5.53x10 <sup>-11</sup>	
Pu-239	4.00x10 <sup>-7</sup>	4.06x10 <sup>-7</sup>	0	0	2.79x10 <sup>-10</sup>	0	1.37x10 <sup>-12</sup>	7.15x10 <sup>-12</sup>	2.00x10 <sup>-9</sup>	
Pu-240	1.06x10 <sup>-7</sup>	1.06x10 <sup>-7</sup>	0	0	6.08x10 <sup>-11</sup>	0	3.65x10 <sup>-13</sup>	1.90x10 <sup>-12</sup>	5.32x10 <sup>-10</sup>	
Pu-241	3.77x10 <sup>-7</sup>	3.77x10 <sup>-7</sup>	0	0	2.16x10 <sup>-10</sup>	0	1.29x10 <sup>-12</sup>	6.74x10 <sup>-12</sup>	1.89x10 <sup>-9</sup>	
Pu-242	1.56x10 <sup>-11</sup>	1.56x10 <sup>-11</sup>	0	0	8.92x10 <sup>-15</sup>	0	5.35x10 <sup>-17</sup>	2.79x10 <sup>-16</sup>	7.81x10 <sup>-14</sup>	
Am-241	1.99x10 <sup>-9</sup>	1.99x10 <sup>-9</sup>	0	0	1.14x10 <sup>-12</sup>	0	6.82x10 <sup>-15</sup>	3.55x10 <sup>-14</sup>	9.94x10 <sup>-12</sup>	
Cs-137	0	0	0	0	4.3x10 <sup>-9</sup>	4.0x10 <sup>-5</sup>	0	1.37x10 <sup>-10</sup>	3.8x10 <sup>-8</sup>	
Kr-83m	0	0	11	110	0	0	0	0	0	
Kr-85m	0	0	7.1	71	0	0	0	0	0	
Kr-85	0	0	8.1x10 <sup>-5</sup>	8.1x10 <sup>-4</sup>	0	0	0	0	0	
Kr-87	0	0	43	430	0	0	0	0	0	
Kr-88	0	0	23	230	0	0	0	0	0	
Kr-89	0	0	1.3x10 <sup>3</sup>	1.3x10 <sup>4</sup>	0	0	0	0	0	

**Table M.5.3.6.1-3. Ceramic Immobilization Alternative Evaluation Basis Accident Source Terms—Continued**

Accident Parameter	Earthquake	Glovebox Fire	Glovebox Nuclear	Mixing Tank			Bellows Drop	Cs Capsule Drop	Plutonyl Nitrate Dissolver			Calciner Feed Spill	Calciner Product Spill
				Criticality <sup>a</sup>	Criticality <sup>a</sup>	Criticality <sup>a</sup>			Spill	Spill	Spill		
Xe-131m	0	0	0.01	0.1	0	0	0	0	0	0	0	0	0
Xe-133m	0	0	0.22	2.2	0	0	0	0	0	0	0	0	0
Xe-133	0	0	2.7	27	0	0	0	0	0	0	0	0	0
Xe-135m	0	0	330	3.3x10 <sup>3</sup>	0	0	0	0	0	0	0	0	0
Xe-135	0	0	41	410	0	0	0	0	0	0	0	0	0
Xe-137	0	0	4.9x10 <sup>3</sup>	4.9x10 <sup>4</sup>	0	0	0	0	0	0	0	0	0
Xe-138	0	0	1.1x10 <sup>3</sup>	1.1x10 <sup>4</sup>	0	0	0	0	0	0	0	0	0
I-131	0	0	0.28	2.75	0	0	0	0	0	0	0	0	0
I-132	0	0	30	300	0	0	0	0	0	0	0	0	0
I-133	0	0	4	40	0	0	0	0	0	0	0	0	0
I-134	0	0	108	1.08x10 <sup>3</sup>	0	0	0	0	0	0	0	0	0
I-135	0	0	11.3	113	0	0	0	0	0	0	0	0	0

<sup>a</sup> Curies produced (by isotope) for the 1.0x10<sup>18</sup> and 1.0x10<sup>19</sup> fission criticalities were scaled from Table M.5.3.1.1-3.

<sup>b</sup> Midpoint of estimated frequency range.

Note: NA=not applicable.

Source: Derived from Tables M.5.1.3.4-1, M.5.3.1.1-3, and M.5.3.6.1-1.

**Table M.5.3.6.1-4. Ceramic Immobilization Alternative Beyond Evaluation Basis Accident Source Terms**

Accident Parameter	Accident Scenario			Uncontrolled Chemical Reaction
	Cs Fire	Process Cell Fire	Nuclear Criticality <sup>a</sup>	
Frequency of occurrence (per year) <sup>b</sup>	$1.0 \times 10^{-6}$	$1.0 \times 10^{-6}$	$1.0 \times 10^{-6}$	$1.0 \times 10^{-6}$
Pu released to environment (g)	NA	$5.0 \times 10^{-7}$	NA	$2.5 \times 10^{-7}$ g
Cs released to environment (Ci)	$1.3 \times 10^{-5}$	NA	NA	$2.74 \times 10^{-7}$
Fissions	NA	NA	$3.0 \times 10^{20}$	NA
<b>Isotope Released to Environment (Ci)</b>				
Pu-238	0	$7.9 \times 10^{-10}$	0	$3.95 \times 10^{-10}$
Pu-239	0	$2.86 \times 10^{-8}$	0	$1.43 \times 10^{-8}$
Pu-240	0	$7.60 \times 10^{-9}$	0	$3.80 \times 10^{-9}$
Pu-241	0	$2.69 \times 10^{-8}$	0	$1.35 \times 10^{-8}$
Pu-242	0	$1.12 \times 10^{-12}$	0	$5.58 \times 10^{-13}$
Am-241	0	$1.42 \times 10^{-10}$	0	$7.10 \times 10^{-11}$
Cs-137	$1.3 \times 10^{-5}$	0	0	$2.74 \times 10^{-7}$
Kr-83m	0	0	$3.3 \times 10^3$	0
Kr-85m	0	0	$2.13 \times 10^3$	0
Kr-85	0	0	0.0243	0
Kr-87	0	0	$1.29 \times 10^4$	0
Kr-88	0	0	$6.90 \times 10^3$	0
Kr-89	0	0	$3.90 \times 10^5$	0
Xe-131m	0	0	3.0	0
Xe-133m	0	0	66	0
Xe-133	0	0	810	0
Xe-135m	0	0	$9.9 \times 10^4$	0
Xe-135	0	0	$1.23 \times 10^4$	0
Xe-137	0	0	$1.47 \times 10^6$	0
Xe-138	0	0	$3.3 \times 10^5$	0
I-131	0	0	82.5	0
I-132	0	0	$9.0 \times 10^3$	0
I-133	0	0	$1.2 \times 10^3$	0
I-134	0	0	$3.23 \times 10^4$	0
I-135	0	0	$3.38 \times 10^3$	0

<sup>a</sup> Curies produced (by isotope) for the  $3.0 \times 10^{20}$  fission criticality was scaled from Table M.5.3.1.1-3.

<sup>b</sup> Midpoint of estimated frequency range.

Note: NA=not applicable.

Source: Derived from Tables M.5.1.3.4-1, M.5.3.1.1-3, and M.5.3.6.1-2.

**Table M.5.3.6.1-5. Accident Scenario Descriptions for Ceramic Immobilization Alternative**

<b>Accident Scenario</b>	<b>Accident Description</b>
<b>Evaluation Basis Accidents</b>	
Earthquake	It is assumed that the earthquake starts a fire in the room housing the Pu metal glovebox line. The fire is unimpeded and breaches a glovebox containing Pu. The glovebox inert atmosphere is lost and the Pu ignites. The ventilation system removes the Pu-containing gases from the area. The gasses pass through HEPA filters and are then released to the environment.
Glovebox fire	It is assumed that an unimpeded fire begins in the room housing the Pu metal glovebox line and breaches a glovebox containing Pu. The glovebox inert atmosphere is lost and the Pu ignites. The ventilation system removes the Pu-containing gases from the area. The gases pass through HEPA filters and are then released to the environment.
Glovebox nuclear criticality	It is assumed that controls are violated so that additional fissile material is introduced into a double batched glovebox. This results in a criticality.
Mixing tank nuclear criticality	It is assumed that controls are violated so that limits on fissile materials and poison controls are violated. A pulsed criticality event results.
Bellows drop	A bellows is dropped 6 m during handling. The force of the drop fractures the ceramic material and ruptures the bellows. Respirable fines of ceramic are released to the cell and collected by the ventilation system. The airborne fines pass through HEPA filters and are released to the environment.
Cs capsule drop	A capsule is dropped 6 m during handling. The force of the drop fractures the CsCl material and ruptures the capsule. Respirable fines of CsCl are released to the cell and collected by the ventilation system. The airborne fines pass through HEPA filters and are released to the environment.
Plutonyl nitrate dissolver spill	It is postulated that the dissolver overflows the spills onto the floor. The spill spreads out in a safe geometry. The spill is cleaned up in two hours but some of the spill material is aerosolized and becomes airborne as respirable particles. The Pu-containing particulate would be removed from the process area by the ventilation system. The particulate then passes through a HEPA filtration system before it is released to the environment.
Calciner feed spill	It is postulated that the calciner feed make-up tank overflows and spills onto the floor. The spill spreads out in a safe geometry. The spill is cleaned up in two hours but some of the spill material is aerosolized and becomes airborne as respirable particles. The Pu-containing particulate would be removed from the process area by the ventilation system. The particulate then passes through a HEPA filtration system before it is released to the environment.
Calciner product spill	It is postulated that the calciner product bin overflow and spills powder onto the floor. The spill spreads out in a safe geometry. The spill is cleaned up in two hours but some of the spill becomes airborne as respirable particles. The Pu-containing particulate would be removed from the process area by the ventilation system. The particulate then passes through a HEPA filtration system before it is released to the environment.
<b>Beyond Evaluation Basis Accidents</b>	
Cs fire	The combustible load for the processes involving Cs is very low. The Cs is in the form of CsCl which is not flammable. A large fire was postulated in the process area and all Cs effected by the fire was released to the area ventilation system and passes through HEPA filters before release to the environment.
Process cell fire	The combustible load in the remote process cells is very low. The process involves no flammable material. A large fire was postulated in the process cell. It is assumed that the fire ruptures the calciner product bins and the contents are exposed to the fire. The resultant airborne material is removed by the area ventilation system and passed through HEPA filters before release to the environment.

***Table M.5.3.6.1–5. Accident Scenario Descriptions for Ceramic Immobilization Alternative—Continued***

<b>Accident Scenario</b>	<b>Accident Description</b>
Nuclear criticality	A criticality event was assumed to occur in the facility and the assumed criticality accident severity is based on guidance provided in NRC Regulatory Guide 3.35.
Uncontrolled chemical reaction	Radiolytic hydrogen will be produced in the solutions in the facility. It was assumed that hydrogen accumulated within tanks because the tanks were isolated from the gas treatment system from a considerable period of time. It was postulated that hydrogen detonated in the calciner feed tank and some of the tank contents became airborne. The resultant airborne material is removed by the area ventilation system and passed through HEPA filters before release to the environment.

Source: LLNL 1996d.

#### **M.5.3.6.2    *Accident Impacts***

The estimated impacts of the postulated accidents at each site are provided in Tables M.5.3.6.2–1 through M.5.3.6.2–6. The dose and cancer fatality estimates are based on the analysis of the accident source terms in Tables M.5.3.6.1–3 and M.5.3.6.1–4 using the MACCS computer code. [Text deleted.]

**Table M.5.3.6.2-1. Ceramic Immobilization Alternative Accident Impacts at Hanford Site**

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (person-rem)	Cancer Fatalities <sup>b</sup>
Earthquake	2.0x10 <sup>-6</sup>	7.9x10 <sup>-10</sup>	1.6x10 <sup>-8</sup>	7.9x10 <sup>-12</sup>	1.2x10 <sup>-4</sup>	5.8x10 <sup>-8</sup>
Glovebox fire	2.0x10 <sup>-6</sup>	7.9x10 <sup>-10</sup>	1.6x10 <sup>-8</sup>	7.9x10 <sup>-12</sup>	1.2x10 <sup>-4</sup>	5.8x10 <sup>-8</sup>
Glovebox criticality	3.5x10 <sup>-3</sup>	1.4x10 <sup>-6</sup>	2.3x10 <sup>-5</sup>	1.2x10 <sup>-8</sup>	0.032	1.6x10 <sup>-5</sup>
Mixing tank criticality	0.035	1.4x10 <sup>-5</sup>	2.3x10 <sup>-4</sup>	1.2x10 <sup>-7</sup>	0.32	1.6x10 <sup>-4</sup>
Bellows drop	1.5x10 <sup>-9</sup>	5.8x10 <sup>-13</sup>	1.1x10 <sup>-11</sup>	5.5x10 <sup>-15</sup>	9.7x10 <sup>-8</sup>	4.9x10 <sup>-11</sup>
Cesium capsule drop	3.0x10 <sup>-6</sup>	1.2x10 <sup>-9</sup>	1.8x10 <sup>-8</sup>	9.2x10 <sup>-12</sup>	2.9x10 <sup>-4</sup>	1.5x10 <sup>-7</sup>
Plutonyl nitrate dissolver spill	6.8x10 <sup>-12</sup>	2.7x10 <sup>-15</sup>	5.4x10 <sup>-14</sup>	2.7x10 <sup>-17</sup>	4.0x10 <sup>-10</sup>	2.0x10 <sup>-13</sup>
Calciner feed spill	4.6x10 <sup>-11</sup>	1.8x10 <sup>-14</sup>	3.5x10 <sup>-13</sup>	1.7x10 <sup>-16</sup>	3.1x10 <sup>-9</sup>	1.5x10 <sup>-12</sup>
Calciner product spill	1.3x10 <sup>-8</sup>	5.1x10 <sup>-12</sup>	9.7x10 <sup>-11</sup>	4.8x10 <sup>-14</sup>	8.5x10 <sup>-7</sup>	4.3x10 <sup>-10</sup>
Cesium fire	9.8x10 <sup>-7</sup>	3.9x10 <sup>-10</sup>	6.0x10 <sup>-9</sup>	3.0x10 <sup>-12</sup>	9.5x10 <sup>-5</sup>	4.7x10 <sup>-8</sup>
Process cell fire	1.4x10 <sup>-7</sup>	5.7x10 <sup>-11</sup>	1.1x10 <sup>-9</sup>	5.7x10 <sup>-13</sup>	8.2x10 <sup>-6</sup>	4.1x10 <sup>-9</sup>
Criticality	1.0	4.2x10 <sup>-4</sup>	6.9x10 <sup>-3</sup>	3.5x10 <sup>-6</sup>	9.5	4.8x10 <sup>-3</sup>
Uncontrolled chemical reaction	9.1x10 <sup>-8</sup>	3.7x10 <sup>-11</sup>	7.0x10 <sup>-10</sup>	3.5x10 <sup>-13</sup>	6.1x10 <sup>-6</sup>	3.1x10 <sup>-9</sup>
[Text deleted.]						1.0x10 <sup>-6</sup>

<sup>a</sup> Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

<sup>b</sup> Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Note: All values are mean values.

Source: Calculated using the source terms in Tables M.5.3.6.1-3 and M.5.3.6.1-4 and the MACCS computer code.

**Table M.5.3.6.2-2. Ceramic Immobilization Alternative Accident Impacts at Nevada Test Site**

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (person-rem)	Number of Cancer Fatalities <sup>b</sup>
Earthquake	$1.4 \times 10^{-6}$	$5.4 \times 10^{-10}$	$2.5 \times 10^{-8}$	$1.3 \times 10^{-11}$	$2.6 \times 10^{-6}$	$1.3 \times 10^{-9}$
Glovebox fire	$1.4 \times 10^{-6}$	$5.4 \times 10^{-10}$	$2.5 \times 10^{-8}$	$1.3 \times 10^{-11}$	$2.6 \times 10^{-6}$	$1.3 \times 10^{-9}$
Glovebox criticality	$2.5 \times 10^{-3}$	$1.0 \times 10^{-6}$	$4.5 \times 10^{-5}$	$2.3 \times 10^{-8}$	$6.5 \times 10^{-4}$	$3.3 \times 10^{-7}$
Mixing tank criticality	0.025	$1.0 \times 10^{-5}$	$4.5 \times 10^{-4}$	$2.3 \times 10^{-7}$	$6.5 \times 10^{-3}$	$3.3 \times 10^{-6}$
Bellows drop	$9.9 \times 10^{-10}$	$4.0 \times 10^{-13}$	$1.8 \times 10^{-11}$	$8.8 \times 10^{-15}$	$2.2 \times 10^{-9}$	$1.1 \times 10^{-12}$
Cesium capsule drop	$2.0 \times 10^{-6}$	$8.1 \times 10^{-10}$	$3.0 \times 10^{-8}$	$1.5 \times 10^{-11}$	$6.7 \times 10^{-6}$	$3.4 \times 10^{-9}$
Plutonyl nitrate dissolver spill	$4.7 \times 10^{-12}$	$1.9 \times 10^{-15}$	$8.6 \times 10^{-14}$	$4.3 \times 10^{-17}$	$8.9 \times 10^{-12}$	$4.5 \times 10^{-15}$
Calciner feed spill	$3.1 \times 10^{-11}$	$1.2 \times 10^{-14}$	$5.5 \times 10^{-13}$	$2.8 \times 10^{-16}$	$7.0 \times 10^{-11}$	$3.5 \times 10^{-14}$
Calciner product spill	$8.7 \times 10^{-9}$	$3.5 \times 10^{-12}$	$1.5 \times 10^{-10}$	$7.7 \times 10^{-14}$	$2.0 \times 10^{-8}$	$9.7 \times 10^{-12}$
Cesium fire	$6.6 \times 10^{-7}$	$2.6 \times 10^{-10}$	$9.8 \times 10^{-9}$	$4.9 \times 10^{-12}$	$2.2 \times 10^{-6}$	$1.1 \times 10^{-9}$
Process cell fire	$9.7 \times 10^{-8}$	$3.9 \times 10^{-11}$	$1.8 \times 10^{-9}$	$9.0 \times 10^{-13}$	$1.9 \times 10^{-7}$	$9.3 \times 10^{-11}$
Criticality	0.76	$3.0 \times 10^{-4}$	0.014	$6.8 \times 10^{-6}$	0.20	$9.7 \times 10^{-5}$
Uncontrolled chemical reaction	$6.2 \times 10^{-8}$	$2.5 \times 10^{-11}$	$1.1 \times 10^{-9}$	$5.5 \times 10^{-13}$	$1.4 \times 10^{-7}$	$7.0 \times 10^{-11}$
[Text deleted.]						

<sup>a</sup> Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

<sup>b</sup> Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Note: All values are mean values.

Source: Calculated using the source terms in Tables M.5.3.6.1-3 and M.5.3.6.1-4 and the MACCS computer code.

**Table M.5.3.6.2-3. Ceramic Immobilization Alternative Accident Impacts at Idaho National Engineering Laboratory**

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (person·rem)	Number of Cancer Fatalities <sup>b</sup>
Earthquake	1.9x10 <sup>-6</sup>	7.4x10 <sup>-10</sup>	1.6x10 <sup>-8</sup>	8.0x10 <sup>-12</sup>	3.5x10 <sup>-5</sup>	1.7x10 <sup>-8</sup>
Glovebox fire	1.9x10 <sup>-6</sup>	7.4x10 <sup>-10</sup>	1.6x10 <sup>-8</sup>	8.0x10 <sup>-12</sup>	3.5x10 <sup>-5</sup>	1.7x10 <sup>-8</sup>
Glovebox nuclear criticality	3.4x10 <sup>-3</sup>	1.4x10 <sup>-6</sup>	2.7x10 <sup>-5</sup>	1.3x10 <sup>-8</sup>	8.7x10 <sup>-3</sup>	4.3x10 <sup>-6</sup>
Mixing tank nuclear criticality	0.034	1.4x10 <sup>-5</sup>	2.7x10 <sup>-4</sup>	1.3x10 <sup>-7</sup>	0.086	4.3x10 <sup>-5</sup>
Bellows drop	1.3x10 <sup>-9</sup>	5.4x10 <sup>-13</sup>	1.1x10 <sup>-11</sup>	5.5x10 <sup>-15</sup>	3.0x10 <sup>-8</sup>	1.5x10 <sup>-11</sup>
Cesium capsule drop	2.6x10 <sup>-6</sup>	1.1x10 <sup>-9</sup>	1.8x10 <sup>-8</sup>	8.8x10 <sup>-12</sup>	9.2x10 <sup>-5</sup>	4.6x10 <sup>-8</sup>
Plutonyl nitrate dissolver spill	6.4x10 <sup>-12</sup>	2.5x10 <sup>-15</sup>	5.5x10 <sup>-14</sup>	2.8x10 <sup>-17</sup>	1.2x10 <sup>-10</sup>	5.9x10 <sup>-14</sup>
Calciner feed spill	4.2x10 <sup>-11</sup>	1.7x10 <sup>-14</sup>	3.5x10 <sup>-13</sup>	1.7x10 <sup>-16</sup>	9.3x10 <sup>-10</sup>	4.7x10 <sup>-13</sup>
Calciner product spill	1.2x10 <sup>-8</sup>	4.7x10 <sup>-12</sup>	9.7x10 <sup>-11</sup>	4.8x10 <sup>-14</sup>	2.6x10 <sup>-7</sup>	1.3x10 <sup>-10</sup>
Cesium fire	8.6x10 <sup>-7</sup>	3.4x10 <sup>-10</sup>	5.7x10 <sup>-9</sup>	2.9x10 <sup>-12</sup>	3.0x10 <sup>-5</sup>	1.5x10 <sup>-8</sup>
Process cell fire	1.3x10 <sup>-7</sup>	5.3x10 <sup>-11</sup>	1.1x10 <sup>-9</sup>	5.7x10 <sup>-13</sup>	2.5x10 <sup>-6</sup>	1.2x10 <sup>-9</sup>
Nuclear criticality	1.0	4.0x10 <sup>-4</sup>	8.1x10 <sup>-3</sup>	4.0x10 <sup>-6</sup>	2.6	1.3x10 <sup>-3</sup>
Uncontrolled chemical reaction	8.4x10 <sup>-8</sup>	3.4x10 <sup>-11</sup>	6.9x10 <sup>-10</sup>	3.5x10 <sup>-13</sup>	1.9x10 <sup>-6</sup>	9.3x10 <sup>-10</sup>
[Text deleted.]						

<sup>a</sup> Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

<sup>b</sup> Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred. All values are mean values.

Calculated using the source terms in Tables M.5.3.6.1-3 and M.5.3.6.1-4 and the MACCS computer code.

**Table M.5.3.6.2-4. Ceramic Immobilization Alternative Accident Impacts at Pantex Plant**

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Dose (rem)	Probability of Cancer Fatality <sup>a</sup> (rem)	Dose (rem)	Probability of Cancer Fatality <sup>a</sup> (rem)	Dose (person-rem)	Number of Cancer Fatalities <sup>b</sup> (per year)
Earthquake	$8.0 \times 10^{-7}$	$3.2 \times 10^{-10}$	$1.8 \times 10^{-7}$	$9.2 \times 10^{-11}$	$3.9 \times 10^{-5}$	$2.0 \times 10^{-8}$
Glovebox fire	$8.0 \times 10^{-7}$	$3.2 \times 10^{-10}$	$1.8 \times 10^{-7}$	$9.2 \times 10^{-11}$	$3.9 \times 10^{-5}$	$2.0 \times 10^{-8}$
Glovebox nuclear criticality	$1.5 \times 10^{-3}$	$6.2 \times 10^{-7}$	$4.4 \times 10^{-4}$	$2.2 \times 10^{-7}$	0.019	$9.5 \times 10^{-6}$
Mixing tank nuclear criticality	0.015	$6.2 \times 10^{-6}$	$4.4 \times 10^{-3}$	$2.2 \times 10^{-6}$	0.19	$9.5 \times 10^{-5}$
Bellows drop	$6.0 \times 10^{-10}$	$2.4 \times 10^{-13}$	$1.3 \times 10^{-10}$	$6.7 \times 10^{-14}$	$3.2 \times 10^{-8}$	$1.6 \times 10^{-11}$
Cesium capsule drop	$1.3 \times 10^{-6}$	$5.1 \times 10^{-10}$	$2.7 \times 10^{-7}$	$1.3 \times 10^{-10}$	$8.8 \times 10^{-5}$	$4.4 \times 10^{-8}$
Plutonyl nitrate dissolver spill	$2.7 \times 10^{-12}$	$1.1 \times 10^{-15}$	$6.3 \times 10^{-13}$	$3.2 \times 10^{-16}$	$1.4 \times 10^{-10}$	$6.7 \times 10^{-14}$
Calciner feed spill	$1.9 \times 10^{-11}$	$7.5 \times 10^{-15}$	$4.2 \times 10^{-12}$	$2.1 \times 10^{-15}$	$1.0 \times 10^{-9}$	$5.0 \times 10^{-13}$
Calciner product spill	$5.2 \times 10^{-9}$	$2.1 \times 10^{-12}$	$1.2 \times 10^{-9}$	$5.9 \times 10^{-13}$	$2.8 \times 10^{-7}$	$1.4 \times 10^{-10}$
Cesium fire	$4.2 \times 10^{-7}$	$1.7 \times 10^{-10}$	$8.7 \times 10^{-8}$	$4.4 \times 10^{-11}$	$2.9 \times 10^{-5}$	$1.4 \times 10^{-8}$
Process cell fire	$5.7 \times 10^{-8}$	$2.3 \times 10^{-11}$	$1.3 \times 10^{-8}$	$6.6 \times 10^{-12}$	$2.8 \times 10^{-6}$	$1.4 \times 10^{-9}$
Nuclear criticality	0.46	$1.9 \times 10^{-4}$	0.13	$6.5 \times 10^{-5}$	5.7	$2.8 \times 10^{-3}$
Uncontrolled chemical reaction	$3.7 \times 10^{-8}$	$1.5 \times 10^{-11}$	$8.5 \times 10^{-9}$	$4.2 \times 10^{-12}$	$2.0 \times 10^{-6}$	$1.0 \times 10^{-9}$
[Text deleted.]						

<sup>a</sup> Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

<sup>b</sup> Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

All values are mean values.

Calculated using the source terms in Tables M.5.3.6.1-3 and M.5.3.6.1-4 and the MACCS computer code.

**Table M.5.3.6.2-5. Ceramic Immobilization Alternative Accident Impacts at Oak Ridge Reservation**

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (person·rem)	Number of Cancer Fatalities <sup>b</sup>
Earthquake	1.8x10 <sup>-6</sup>	7.3x10 <sup>-10</sup>	3.2x10 <sup>-7</sup>	1.6x10 <sup>-10</sup>	2.8x10 <sup>-4</sup>	1.4x10 <sup>-7</sup>
Glovebox fire	1.8x10 <sup>-6</sup>	7.3x10 <sup>-10</sup>	3.2x10 <sup>-7</sup>	1.6x10 <sup>-10</sup>	2.8x10 <sup>-4</sup>	1.4x10 <sup>-7</sup>
Glovebox nuclear criticality	3.2x10 <sup>-3</sup>	1.3x10 <sup>-6</sup>	5.8x10 <sup>-4</sup>	2.9x10 <sup>-7</sup>	0.13	6.3x10 <sup>-5</sup>
Mixing tank nuclear criticality	0.032	1.3x10 <sup>-5</sup>	5.8x10 <sup>-3</sup>	2.9x10 <sup>-6</sup>	1.3	6.3x10 <sup>-4</sup>
Bellows drop	1.4x10 <sup>-9</sup>	5.5x10 <sup>-13</sup>	2.4x10 <sup>-10</sup>	1.2x10 <sup>-13</sup>	2.3x10 <sup>-7</sup>	1.1x10 <sup>-10</sup>
Cesium capsule drop	2.9x10 <sup>-6</sup>	1.2x10 <sup>-9</sup>	4.7x10 <sup>-7</sup>	2.4x10 <sup>-10</sup>	6.1x10 <sup>-4</sup>	3.1x10 <sup>-7</sup>
Plutonyl nitrate dissolver spill	6.3x10 <sup>-12</sup>	2.5x10 <sup>-15</sup>	1.1x10 <sup>-12</sup>	5.5x10 <sup>-16</sup>	9.6x10 <sup>-10</sup>	4.8x10 <sup>-13</sup>
Calciner feed spill	4.3x10 <sup>-11</sup>	1.7x10 <sup>-14</sup>	7.4x10 <sup>-12</sup>	3.7x10 <sup>-15</sup>	7.1x10 <sup>-9</sup>	3.5x10 <sup>-12</sup>
Calciner product spill	1.2x10 <sup>-8</sup>	4.8x10 <sup>-12</sup>	2.1x10 <sup>-9</sup>	1.0x10 <sup>-12</sup>	2.0x10 <sup>-6</sup>	9.9x10 <sup>-10</sup>
Cesium fire	9.5x10 <sup>-7</sup>	3.8x10 <sup>-10</sup>	1.5x10 <sup>-7</sup>	7.7x10 <sup>-11</sup>	2.0x10 <sup>-4</sup>	9.9x10 <sup>-8</sup>
Process cell fire	1.3x10 <sup>-7</sup>	5.3x10 <sup>-11</sup>	2.3x10 <sup>-8</sup>	1.2x10 <sup>-11</sup>	2.0x10 <sup>-5</sup>	1.0x10 <sup>-8</sup>
Nuclear criticality	0.94	3.8x10 <sup>-4</sup>	0.17	8.6x10 <sup>-5</sup>	37.4	0.019
Uncontrolled chemical reaction	8.6x10 <sup>-8</sup>	3.4x10 <sup>-11</sup>	1.5x10 <sup>-8</sup>	7.3x10 <sup>-12</sup>	0.14x10 <sup>-5</sup>	7.1x10 <sup>-9</sup>
[Text deleted.]						

<sup>a</sup> Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary [1,000 m for this facility at ORR], whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

<sup>b</sup> Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Note: All values are mean values.

Source: Calculated using the source terms in Tables M.5.3.6.1-3 and M.5.3.6.1-4 and the MACCS computer code.

**Table M.5.3.6.2-6. Ceramic Immobilization Alternative Accident Impacts at Savannah River Site**

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (rem)	Probability of Cancer Fatality <sup>a</sup>	Dose (person-rem)	Number of Cancer Fatalities <sup>b</sup>
Earthquake	$1.3 \times 10^{-6}$	$5.2 \times 10^{-10}$	$2.6 \times 10^{-8}$	$1.3 \times 10^{-11}$	$1.2 \times 10^{-4}$	$6.2 \times 10^{-8}$
Glovebox fire	$1.3 \times 10^{-6}$	$5.2 \times 10^{-10}$	$2.6 \times 10^{-8}$	$1.3 \times 10^{-11}$	$1.2 \times 10^{-4}$	$6.2 \times 10^{-8}$
Glovebox nuclear criticality	$2.3 \times 10^{-3}$	$9.1 \times 10^{-7}$	$4.0 \times 10^{-5}$	$2.0 \times 10^{-8}$	0.041	$2.0 \times 10^{-5}$
Mixing tank nuclear criticality	0.023	$9.1 \times 10^{-6}$	$4.0 \times 10^{-4}$	$2.0 \times 10^{-7}$	0.41	$2.0 \times 10^{-4}$
Bellows drop	$9.7 \times 10^{-10}$	$3.9 \times 10^{-13}$	$1.9 \times 10^{-11}$	$9.3 \times 10^{-15}$	$1.0 \times 10^{-7}$	$5.1 \times 10^{-11}$
Cesium capsule drop	$2.1 \times 10^{-6}$	$8.4 \times 10^{-10}$	$3.8 \times 10^{-8}$	$1.9 \times 10^{-11}$	$2.9 \times 10^{-4}$	$1.5 \times 10^{-7}$
Plutonyl nitrate dissolver spill	$4.5 \times 10^{-12}$	$1.8 \times 10^{-15}$	$8.8 \times 10^{-14}$	$4.4 \times 10^{-17}$	$4.2 \times 10^{-10}$	$2.1 \times 10^{-13}$
Calciner feed spill	$3.0 \times 10^{-11}$	$1.2 \times 10^{-14}$	$5.9 \times 10^{-13}$	$2.9 \times 10^{-16}$	$3.2 \times 10^{-9}$	$1.6 \times 10^{-12}$
Calciner product spill	$8.5 \times 10^{-9}$	$3.4 \times 10^{-12}$	$1.6 \times 10^{-10}$	$8.2 \times 10^{-12}$	$9.0 \times 10^{-7}$	$4.5 \times 10^{-10}$
Cesium fire	$6.8 \times 10^{-7}$	$2.7 \times 10^{-10}$	$1.2 \times 10^{-8}$	$6.1 \times 10^{-12}$	$9.5 \times 10^{-5}$	$4.7 \times 10^{-8}$
Process cell fire	$9.3 \times 10^{-8}$	$3.7 \times 10^{-11}$	$1.8 \times 10^{-9}$	$9.1 \times 10^{-13}$	$8.8 \times 10^{-6}$	$4.4 \times 10^{-9}$
Nuclear criticality	0.68	$2.7 \times 10^{-4}$	0.012	$6.0 \times 10^{-6}$	12.2	$6.1 \times 10^{-3}$
Uncontrolled chemical reaction	$6.1 \times 10^{-8}$	$2.4 \times 10^{-11}$	$1.2 \times 10^{-9}$	$5.9 \times 10^{-13}$	$6.4 \times 10^{-6}$	$3.2 \times 10^{-9}$
[Text deleted.]						

<sup>a</sup> Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

<sup>b</sup> Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Note: All values are mean values.

Source: Calculated using the source terms in Tables M.5.3.6.1-3 and M.5.3.6.1-4 and the MACCS computer code.